

## SEQUENCE LISTING

<110> National Institutes of Health  
5 Qasba, Pradman  
Boeggeman, Elizabeth  
Ramakrishnan, Boopathy

<120> Catalytic Domains Of Beta(1,4)-Galactosyltransferase I Having  
10 Altered Metal Ion Specificity

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20<212> PRT  
<213> Homo sapiens

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&lt;210&gt; 4

&lt;211&gt; 398

&lt;212&gt; PRT

&lt;213&gt; Homo sapiens

5

&lt;400&gt; 4

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Ala Ser Leu Gln Arg Ala Cys Arg Leu Leu Val Ala Val Cys Ala Leu
10           20           25           30
His Leu Gly Val Thr Leu Val Tyr Tyr Leu Ala Gly Arg Asp Leu Ser
 35           40           45
Arg Leu Pro Gln Leu Val Gly Val Ser Thr Pro Leu Gln Gly Gly Ser
 50           55           60
15Asn Ser Ala Ala Ala Ile Gly Gln Ser Ser Gly Asp Leu Arg Thr Gly
 65           70           75           80
Gly Ala Arg Pro Pro Pro Pro Leu Gly Ala Ser Ser Gln Pro Arg Pro
 85           90           95
Gly Gly Asp Ser Ser Pro Val Val Asp Ser Gly Pro Gly Pro Ala Ser
20           100           105           110
Asn Leu Thr Ser Val Pro Val Pro His Thr Thr Ala Leu Ser Leu Pro
 115           120           125
Ala Cys Pro Glu Glu Ser Pro Leu Leu Val Gly Pro Met Leu Ile Glu
 130           135           140
25Phe Asn Met Pro Val Asp Leu Glu Leu Val Ala Lys Gln Asn Pro Asn
 145           150           155           160
Val Lys Met Gly Gly Arg Tyr Ala Pro Arg Asp Cys Val Ser Pro His
 165           170           175
Lys Val Ala Ile Ile Ile Pro Phe Arg Asn Arg Gln Glu His Leu Lys
30           180           185           190
Tyr Trp Leu Tyr Tyr Leu His Pro Val Leu Gln Arg Gln Gln Leu Asp
 195           200           205
Tyr Gly Ile Tyr Val Ile Asn Gln Ala Gly Asp Thr Ile Phe Asn Arg
 210           215           220
35Ala Lys Leu Leu Asn Val Gly Phe Gln Glu Ala Leu Lys Asp Tyr Asp
 225           230           235           240
Tyr Thr Cys Phe Val Phe Ser Asp Val Asp Leu Ile Pro Met Asn Asp
 245           250           255
His Asn Ala Tyr Arg Cys Phe Ser Gln Pro Arg His Ile Ser Val Ala
40           260           265           270
Met Asp Lys Phe Gly Phe Ser Leu Pro Tyr Val Gln Tyr Phe Gly Gly
 275           280           285

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Val Ser Ala Ser Ser Lys Gln Gln Phe Leu Thr Ile Asn Gly Phe Pro  
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 Asn Asn Tyr Trp Gly Trp Gly Gly Glu Asp Asp Asp Ile Phe Asn Arg  
 305 310 315 320  
 5Leu Val Phe Arg Gly Met Ser Ile Ser Arg Pro Asn Ala Val Val Gly  
 325 330 335  
 Thr Cys Arg Met Ile Arg His Ser Arg Asp Lys Lys Asn Glu Pro Asn  
 340 345 350  
 Pro Gln Arg Phe Asp Arg Ile Ala His Thr Lys Glu Thr Met Leu Ser  
 10 355 360 365  
 Asp Gly Leu Asn Ser Leu Thr Tyr Gln Val Leu Asp Val Gln Arg Tyr  
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 Pro Leu Tyr Thr Gln Ile Thr Val Asp Ile Gly Thr Pro Ser  
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 His Leu Gly Val Thr Leu Val Tyr Tyr Leu Ser Gly Arg Asp Leu Ser  
 35 40 45  
 Arg Leu Pro Gln Leu Val Gly Val Ser Ser Thr Leu Gln Gly Gly Thr  
 50 55 60  
 30Asn Gly Ala Ala Ala Ser Lys Gln Pro Pro Gly Glu Gln Arg Pro Arg  
 65 70 75 80  
 Gly Ala Arg Pro Pro Pro Pro Leu Gly Val Ser Pro Lys Pro Arg Pro  
 85 90 95  
 Gly Leu Asp Ser Ser Pro Gly Ala Ala Ser Gly Pro Gly Leu Lys Ser  
 35 100 105 110  
 Asn Leu Ser Ser Leu Pro Val Pro Thr Thr Thr Gly Leu Leu Ser Leu  
 115 120 125  
 Pro Ala Cys Pro Glu Glu Ser Pro Leu Leu Val Gly Pro Met Leu Ile  
 130 135 140  
 40Asp Phe Asn Ile Ala Val Asp Leu Glu Leu Leu Ala Lys Lys Asn Pro  
 145 150 155 160

4

Glu Ile Lys Thr Gly Gly Arg Tyr Ser Pro Lys Asp Cys Val Ser Pro  
 165 170 175  
 His Lys Val Ala Ile Ile Ile Pro Phe Arg Asn Arg Gln Glu His Leu  
 180 185 190  
 5Lys Tyr Trp Leu Tyr Tyr Leu His Pro Ile Leu Gln Arg Gln Gln Leu  
 195 200 205  
 Asp Tyr Gly Ile Tyr Val Ile Asn Gln Ala Gly Asp Thr Met Phe Asn  
 210 215 220  
 Arg Ala Lys Leu Leu Asn Ile Gly Phe Gln Glu Ala Leu Lys Asp Tyr  
 10225 230 235 240  
 Asp Tyr Asn Cys Phe Val Phe Ser Asp Val Asp Leu Ile Pro Met Asp  
 245 250 255  
 Asp Arg Asn Ala Tyr Arg Cys Phe Ser Gln Pro Arg His Ile Ser Val  
 260 265 270  
 15Ala Met Asp Lys Phe Gly Phe Ser Leu Pro Tyr Val Gln Tyr Phe Gly  
 275 280 285  
 Gly Val Ser Ala Leu Ser Lys Gln Gln Phe Leu Ala Ile Asn Gly Phe  
 290 295 300  
 Pro Asn Asn Tyr Trp Gly Trp Gly Gly Glu Asp Asp Asp Ile Phe Asn  
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 Arg Leu Val His Lys Gly Met Ser Ile Ser Arg Pro Asn Ala Val Val  
 325 330 335  
 Gly Arg Cys Arg Met Ile Arg His Ser Arg Asp Lys Lys Asn Glu Pro  
 340 345 350  
 25Asn Pro Gln Arg Phe Asp Arg Ile Ala His Thr Lys Glu Thr Met Arg  
 355 360 365  
 Phe Asp Gly Leu Asn Ser Leu Thr Tyr Lys Val Leu Asp Val Gln Arg  
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 Tyr Pro Leu Tyr Thr Gln Ile Thr Val Asp Ile Gly Thr Pro Arg  
 30385 390 395

&lt;210&gt; 6

&lt;211&gt; 402

&lt;212&gt; PRT

35&lt;213&gt; Bos taurus

&lt;400&gt; 6

Met Lys Phe Arg Glu Pro Leu Leu Gly Gly Ser Ala Ala Met Pro Gly  
 1 5 10 15  
 40Ala Ser Leu Gln Arg Ala Cys Arg Leu Val Ala Val Cys Ala Leu  
 20 25 30

His Leu Gly Val Thr Leu Val Tyr Tyr Leu Ala Gly Arg Asp Leu Arg  
 35 40 45  
 Arg Leu Pro Gln Leu Val Gly Val His Pro Pro Leu Gln Gly Ser Ser  
 50 55 60  
 5His Gly Ala Ala Ala Ile Gly Gln Pro Ser Gly Glu Leu Arg Leu Arg  
 65 70 75 80  
 Gly Val Ala Pro Pro Pro Pro Leu Gln Asn Ser Ser Lys Pro Arg Ser  
 85 90 95  
 Arg Ala Pro Ser Asn Leu Asp Ala Tyr Ser His Pro Gly Pro Gly Pro  
 10 100 105 110  
 Gly Pro Gly Ser Asn Leu Thr Ser Ala Pro Val Pro Ser Thr Thr Thr  
 115 120 125  
 Arg Ser Leu Thr Ala Cys Pro Glu Glu Ser Pro Leu Leu Val Gly Pro  
 130 135 140  
 15Met Leu Ile Glu Phe Asn Ile Pro Val Asp Leu Lys Leu Ile Glu Gln  
 145 150 155 160  
 Gln Asn Pro Lys Val Lys Leu Gly Gly Arg Tyr Thr Pro Met Asp Cys  
 165 170 175  
 Ile Ser Pro His Lys Val Ala Ile Ile Ile Leu Phe Arg Asn Arg Gln  
 20 180 185 190  
 Glu His Leu Lys Tyr Trp Leu Tyr Tyr Leu His Pro Met Val Gln Arg  
 195 200 205  
 Gln Gln Leu Asp Tyr Gly Ile Tyr Val Ile Asn Gln Ala Gly Glu Ser  
 210 215 220  
 25Met Phe Asn Arg Ala Lys Leu Leu Asn Val Gly Phe Lys Glu Ala Leu  
 225 230 235 240  
 Lys Asp Tyr Asp Tyr Asn Cys Phe Val Phe Ser Asp Val Asp Leu Ile  
 245 250 255  
 Pro Met Asn Asp His Asn Thr Tyr Arg Cys Phe Ser Gln Pro Arg His  
 30 260 265 270  
 Ile Ser Val Ala Met Asp Lys Phe Gly Phe Ser Leu Pro Tyr Val Gln  
 275 280 285  
 Tyr Phe Gly Gly Val Ser Ala Leu Ser Lys Gln Gln Phe Leu Ser Ile  
 290 295 300  
 35Asn Gly Phe Pro Asn Asn Tyr Trp Gly Trp Gly Gly Glu Asp Asp Asp  
 305 310 315 320  
 Ile Tyr Asn Arg Leu Ala Phe Arg Gly Met Ser Val Ser Arg Pro Asn  
 325 330 335  
 Ala Val Ile Gly Lys Cys Arg Met Ile Arg His Ser Arg Asp Lys Lys  
 40 340 345 350  
 Asn Glu Pro Asn Pro Gln Arg Phe Asp Arg Ile Ala His Thr Lys Glu  
 355 360 365

6

Thr Met Leu Ser Asp Gly Leu Asn Ser Leu Thr Tyr Met Val Leu Glu  
 370 375 380  
 Val Gln Arg Tyr Pro Leu Tyr Thr Lys Ile Thr Val Asp Ile Gly Thr  
 385 390 395 400  
 5Pro Ser

<210> 7  
 <211> 113  
 10<212> PRT  
 <213> Homo sapiens

<400> 7  
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 Gln Gly Gly Ser Asn Ser Ala Ala Ala Ile Gly Gln Ser Ser Gly Asp  
 20 25 30  
 Leu Arg Thr Gly Gly Ala Arg Pro Pro Pro Pro Leu Gly Ala Ser Ser  
 35 40 45  
 20Gln Pro Arg Pro Gly Gly Asp Ser Ser Pro Val Val Asp Ser Gly Pro  
 50 55 60  
 Gly Pro Ala Ser Asn Leu Thr Ser Val Pro Val Pro His Thr Thr Ala  
 65 70 75 80  
 Leu Ser Leu Pro Ala Cys Pro Glu Glu Ser Pro Leu Leu Val Gly Pro  
 25 85 90 95  
 Met Leu Ile Glu Phe Asn Met Pro Val Asp Leu Glu Leu Val Ala Lys  
 100 105 110  
 Gln

30  
 <210> 8  
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 <213> Bos taurus

35  
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 Gln Gly Ser Ser His Gly Ala Ala Ala Ile Gly Gln Pro Ser Gly Glu  
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 Leu Arg Leu Arg Gly Val Ala Pro Pro Pro Pro Leu Gln Asn Ser Ser  
 35 40 45

7

Lys Pro Arg Ser Arg Ala Pro Ser Asn Leu Asp Ala Tyr Ser His Pro  
 50 55 60  
 Gly Pro Gly Pro Gly Pro Gly Ser Asn Leu Thr Ser Ala Pro Val Pro  
 65 70 75 80  
 5Ser Thr Thr Thr Arg  
 85

&lt;210&gt; 9

&lt;211&gt; 273

10&lt;212&gt; PRT

&lt;213&gt; Homo sapiens

&lt;400&gt; 9

Ser Leu Pro Ala Cys Pro Glu Glu Ser Pro Leu Leu Val Gly Pro Met  
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 Leu Ile Glu Phe Asn Met Pro Val Asp Leu Glu Leu Val Ala Lys Gln  
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 Asn Pro Asn Val Lys Met Gly Gly Arg Tyr Ala Pro Arg Asp Cys Val  
 35 40 45  
 20Ser Pro His Lys Val Ala Ile Ile Ile Pro Phe Arg Asn Arg Gln Glu  
 50 55 60  
 His Leu Lys Tyr Trp Leu Tyr Tyr Leu His Pro Val Leu Gln Arg Gln  
 65 70 75 80  
 Gln Leu Asp Tyr Gly Ile Tyr Val Ile Asn Gln Ala Gly Asp Thr Ile  
 25 85 90 95  
 Phe Asn Arg Ala Lys Leu Leu Asn Val Gly Phe Gln Glu Ala Leu Lys  
 100 105 110  
 Asp Tyr Asp Tyr Thr Cys Phe Val Phe Ser Asp Val Asp Leu Ile Pro  
 115 120 125  
 30Met Asn Asp His Asn Ala Tyr Arg Cys Phe Ser Gln Pro Arg His Ile  
 130 135 140  
 Ser Val Ala Met Asp Lys Phe Gly Phe Ser Leu Pro Tyr Val Gln Tyr  
 145 150 155 160  
 Phe Gly Gly Val Ser Ala Ser Ser Lys Gln Gln Phe Leu Thr Ile Asn  
 35 165 170 175  
 Gly Phe Pro Asn Asn Tyr Trp Gly Trp Gly Gly Glu Asp Asp Asp Ile  
 180 185 190  
 Phe Asn Arg Leu Val Phe Arg Gly Met Ser Ile Ser Arg Pro Asn Ala  
 195 200 205  
 40Val Val Gly Thr Cys Arg Met Ile Arg His Ser Arg Asp Lys Lys Asn  
 210 215 220

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Leu	Ile	Glu	Phe	Asn	Ile	Pro	Val	Asp	Leu	Lys	Leu	Ile	Glu	Gln	Gln				
			20					25					30						
20Asn	Pro	Lys	Val	Lys	Leu	Gly	Gly	Arg	Tyr	Thr	Pro	Met	Asp	Cys	Ile				
			35				40						45						
Ser	Pro	His	Lys	Val	Ala	Ile	Ile	Ile	Leu	Phe	Arg	Asn	Arg	Gln	Glu				
			50			55					60								
His	Leu	Lys	Tyr	Trp	Leu	Tyr	Tyr	Leu	His	Pro	Met	Val	Gln	Arg	Gln				
2565				70						75					80				
Gln	Leu	Asp	Tyr	Gly	Ile	Tyr	Val	Ile	Asn	Gln	Ala	Gly	Glu	Ser	Met				
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Phe	Asn	Arg	Ala	Lys	Leu	Leu	Asn	Val	Gly	Phe	Lys	Glu	Ala	Leu	Lys				
			100					105					110						
30Asp	Tyr	Asp	Tyr	Asn	Cys	Phe	Val	Phe	Ser	Asp	Val	Asp	Leu	Ile	Pro				
			115				120						125						
Met	Asn	Asp	His	Asn	Thr	Tyr	Arg	Cys	Phe	Ser	Gln	Pro	Arg	His	Ile				
			130			135					140								
Ser	Val	Ala	Met	Asp	Lys	Phe	Gly	Phe	Ser	Leu	Pro	Tyr	Val	Gln	Tyr				
35145					150					155					160				
Phe	Gly	Gly	Val	Ser	Ala	Leu	Ser	Lys	Gln	Gln	Phe	Leu	Ser	Ile	Asn				
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Gly	Phe	Pro	Asn	Asn	Tyr	Trp	Gly	Trp	Gly	Gly	Glu	Asp	Asp	Asp	Ile				
			180				185						190						
40Tyr	Asn	Arg	Leu	Ala	Phe	Arg	Gly	Met	Ser	Val	Ser	Arg	Pro	Asn	Ala				
			195				200						205						



9

Val Ile Gly Lys Cys Arg Met Ile Arg His Ser Arg Asp Lys Lys Asn  
 210 215 220  
 Glu Pro Asn Pro Gln Arg Phe Asp Arg Ile Ala His Thr Lys Glu Thr  
 225 230 235 240  
 5Met Leu Ser Asp Gly Leu Asn Ser Leu Thr Tyr Met Val Leu Glu Val  
 245 250 255  
 Gln Arg Tyr Pro Leu Tyr Thr Lys Ile Thr Val Asp Ile Gly Thr Pro  
 260 265 270  
 Ser

10

<210> 11  
 <211> 1197  
 <212> PRT  
 15<213> Homo sapiens

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 35 40 45  
 Gly Cys Gly Thr Cys Cys Cys Thr Ala Cys Ala Gly Cys Gly Gly Gly  
 25 50 55 60  
 Cys Cys Thr Gly Cys Cys Gly Cys Cys Thr Gly Cys Thr Cys Gly Thr  
 65 70 75 80  
 Gly Gly Cys Cys Gly Thr Cys Thr Gly Cys Gly Cys Thr Cys Thr Gly  
 85 90 95  
 30Cys Ala Cys Cys Thr Thr Gly Gly Cys Gly Thr Cys Ala Cys Cys Cys  
 100 105 110  
 Thr Cys Gly Thr Thr Thr Ala Cys Thr Ala Cys Cys Thr Gly Gly Cys  
 115 120 125  
 Thr Gly Gly Cys Cys Gly Cys Gly Ala Cys Cys Thr Gly Ala Gly Cys  
 35 130 135 140  
 Cys Gly Cys Cys Thr Gly Cys Cys Cys Cys Ala Ala Cys Thr Gly Gly  
 145 150 155 160  
 Thr Cys Gly Gly Ala Gly Thr Cys Thr Cys Cys Ala Cys Ala Cys Cys  
 165 170 175  
 40Gly Cys Thr Gly Cys Ala Gly Gly Gly Cys Gly Gly Gly Thr Cys Gly  
 180 185 190

10

Ala Ala Cys Ala Gly Thr Gly Cys Cys Gly Cys Cys Gly Cys Cys Ala  
 195 200 205  
 Thr Cys Gly Gly Gly Cys Ala Gly Thr Cys Cys Thr Cys Cys Gly Gly  
 210 215 220  
 5Gly Gly Ala Cys Cys Thr Cys Cys Gly Gly Ala Cys Cys Gly Gly Ala  
 225 230 235 240  
 Gly Gly Gly Gly Cys Cys Cys Gly Gly Cys Cys Gly Cys Cys Gly Cys  
 245 250 255  
 Cys Thr Cys Cys Thr Cys Thr Ala Gly Gly Cys Gly Cys Cys Thr Cys  
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 Cys Thr Cys Cys Cys Ala Gly Cys Cys Gly Cys Gly Cys Cys Cys Gly  
 275 280 285  
 Gly Gly Thr Gly Gly Cys Gly Ala Cys Thr Cys Cys Ala Gly Cys Cys  
 290 295 300  
 15Cys Ala Gly Thr Cys Gly Thr Gly Gly Ala Thr Thr Cys Thr Gly Gly  
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 Cys Cys Cys Thr Gly Gly Cys Cys Cys Cys Gly Cys Thr Ala Gly Cys  
 325 330 335  
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 20 340 345 350  
 Cys Ala Gly Thr Gly Cys Cys Cys Cys Ala Cys Ala Cys Cys Ala Cys  
 355 360 365  
 Cys Gly Cys Ala Cys Thr Gly Thr Cys Gly Cys Thr Gly Cys Cys Cys  
 370 375 380  
 25Gly Cys Cys Thr Gly Cys Cys Cys Thr Gly Ala Gly Gly Ala Gly Thr  
 385 390 395 400  
 Cys Cys Cys Cys Gly Cys Thr Gly Cys Thr Thr Gly Thr Gly Gly Gly  
 405 410 415  
 Cys Cys Cys Cys Ala Thr Gly Cys Thr Gly Ala Thr Thr Gly Ala Gly  
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 Thr Thr Thr Ala Ala Cys Ala Thr Gly Cys Cys Thr Gly Thr Gly Gly  
 435 440 445  
 Ala Cys Cys Thr Gly Gly Ala Gly Cys Thr Cys Gly Thr Gly Gly Cys  
 450 455 460  
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 465 470 475 480  
 Gly Thr Gly Ala Ala Gly Ala Thr Gly Gly Gly Cys Gly Gly Cys Cys  
 485 490 495  
 Gly Cys Thr Ala Thr Gly Cys Cys Cys Cys Cys Ala Gly Gly Gly Ala  
 40 500 505 510  
 Cys Thr Gly Cys Gly Thr Cys Thr Cys Thr Cys Cys Thr Cys Ala Cys  
 515 520 525

11

Ala Ala Gly Gly Thr Gly Gly Cys Cys Ala Thr Cys Ala Thr Cys Ala  
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 Thr Thr Cys Cys Ala Thr Thr Cys Cys Gly Cys Ala Ala Cys Cys Gly  
 545 550 555 560  
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 565 570 575  
 Thr Ala Cys Thr Gly Gly Cys Thr Ala Thr Ala Thr Thr Ala Thr Thr  
 580 585 590  
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 625 630 635 640  
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 645 650 655  
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 660 665 670  
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 20 675 680 685  
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 690 695 700  
 Cys Thr Thr Gly Ala Ala Gly Gly Ala Cys Thr Ala Thr Gly Ala Cys  
 705 710 715 720  
 25Thr Ala Cys Ala Cys Cys Thr Gly Cys Thr Thr Thr Gly Thr Gly Thr  
 725 730 735  
 Thr Thr Ala Gly Thr Gly Ala Cys Gly Thr Gly Gly Ala Cys Cys Thr  
 740 745 750  
 Cys Ala Thr Thr Cys Cys Ala Ala Thr Gly Ala Ala Thr Gly Ala Thr  
 30 755 760 765  
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 770 775 780  
 Gly Thr Thr Thr Thr Thr Cys Ala Cys Ala Gly Cys Cys Ala Cys Gly  
 785 790 795 800  
 35Gly Cys Ala Cys Ala Thr Thr Thr Cys Cys Gly Thr Thr Gly Cys Ala  
 805 810 815  
 Ala Thr Gly Gly Ala Thr Ala Ala Gly Thr Thr Thr Gly Gly Ala Thr  
 820 825 830  
 Thr Cys Ala Gly Cys Cys Thr Ala Cys Cys Thr Thr Ala Thr Gly Thr  
 40 835 840 845  
 Thr Cys Ala Gly Thr Ala Thr Thr Thr Thr Gly Gly Ala Gly Gly Thr  
 850 855 860

12

Gly Thr Cys Thr Cys Thr Gly Cys Thr Thr Cys Ala Ala Gly Thr Ala  
 865 870 875 880  
 Ala Ala Cys Ala Ala Cys Ala Gly Thr Thr Thr Cys Thr Ala Ala Cys  
 885 890 895  
 5Cys Ala Thr Cys Ala Ala Thr Gly Gly Ala Thr Thr Thr Cys Cys Thr  
 900 905 910  
 Ala Ala Thr Ala Ala Thr Thr Ala Thr Thr Gly Gly Gly Gly Cys Thr  
 915 920 925  
 Gly Gly Gly Gly Ala Gly Gly Ala Gly Ala Ala Gly Ala Thr Gly Ala  
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 Thr Gly Ala Cys Ala Thr Thr Thr Thr Thr Ala Ala Cys Ala Gly Ala  
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 15Thr Gly Thr Cys Thr Ala Thr Ala Thr Cys Thr Cys Gly Cys Cys Cys  
 980 985 990  
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 995 1000 1005  
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 30 1090 1095 1100  
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 1105 1110 1115 1120  
 Thr Cys Ala Cys Cys Thr Ala Cys Cys Ala Gly Gly Thr Gly Cys Thr  
 1125 1130 1135  
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13

&lt;210&gt; 12

&lt;211&gt; 36

&lt;212&gt; DNA

&lt;213&gt; Artificial Sequence

5

&lt;220&gt;

&lt;223&gt; A synthetic primer

&lt;400&gt; 12

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36

&lt;210&gt; 13

&lt;211&gt; 36

&lt;212&gt; DNA

15&lt;213&gt; Artificial Sequence

&lt;220&gt;

&lt;223&gt; A synthetic primer

20&lt;400&gt; 13

atcggaaga cgcgtgagat ccgccactcg agagac

36